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Articles PAGE

Astronomy in a Poet's Life - - - - *Albert Durant Watson* 1

The Orbits of the Spectroscopic Components of Boss 4622 *W. E. Harper* 9

Orbit of the Spectroscopic Binary Boss 5442 - *Reynold K. Young* 12

On the Adjustment of Equatorial Telescopes *Howard Grubb* 15

Meetings of the Society - - - - - - - 27

Notes from the Meteorological Service - - - - - 32

Notes and Queries - - - - - - - - 35

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ASTRONOMY IN A POET'S LIFE

BY ALBERT DURRANT WATSON

A seat on the Cassiopean stars,
A quill from the eagle's wing,
Papyrus gleaned from the fens of Mars
With ink of darkness and leave to sing:

I would shape my song to a larger theme
Than shepherds blow from the reeds of Pan;
I would croon to the beat of the Centaur's feet
In tracks where the hounds of Boötes ran.

For I should listen across the night,
And hear the tones of that mightier word
That sings in a far intenser light
The strains of a deep eternal chord.

THE astronomer is more easily defined than the poet; yet they have much in common. The chief instrument of the former is the mathematical process; of the latter, imagination and emotion. The astronomer who uses his imagination is a poet; the poet who applies accurate thought to the problems of the stars is an astronomer. The astronomer will be a better astronomer if he be also a poet, and the poet will be a better poet if he be also an astronomer.

It is not necessary that the astronomer should discover heavenly bodies, nor that the poet should write actual poems. The virtual astronomer thinks in terms of universal law. The essential poet feels in terms of infinite reality. We cannot think truly of the great astronomers without realizing that they are potential poets, and the most significant poets shaped their dreams to the contours of truth in systems fundamental and eternal. Homer, Virgil, Shakespeare, Milton—these were all potential astronomers. They played mighty chords, moving upon the whole gamut of their powers, but they found in the celestial sphere no law or harmony not already established in their own souls. The beauty and symmetry of the external is nothing to him who finds not their counterparts in the final woof of his own being.

The schemes of gods and men, their passions and exploits, their triumphs and their dooms, are all in the repertoire of the poet of vision and power. The diapasons of his art are all tuned to the universal passions. His energy is spiritual as all energy is spiritual. The astronomer, with his intellect alone, can never exhaust the skies, yet the heavens bend down to whisper their secrets to his listening heart. He can never uncover the whole drift of nature, nor can the poet exhaust the full meaning of life. Yet the infinite life, and the all-but-infinite universe are not too vast in scope for their strong far-beating wings. Either of them is as likely to pitch his tent in some distant garden of the Pleiades as in his own meadow.

The lesser astronomer, like the minor poet, is satisfied with local vision and partial interests, with the external qualities of individual stars and flowers, brooks in moonlit valleys, birds and song and domestic affections, but the great poet, like the great astronomer, will link all these with the universal. They must have scope and amplitude for their larger thought, their wider vision and deeper feeling. They drive the intellect to its limit, then drift on wings of inspiration to vaster fields of reality. The true astronomer and the real poet meet in the skies, for there is the habitat of the unboundaried mind which is the possession of all true greatness.

The astronomer and the poet may meet as two persons, or they may both exist in one personality. In the Lowells, they met as brothers. In fact, they always meet as brothers in the larger

sense, the astronomer paramount in supremacy of law, the poet in sublimity of imagination. We have no example where supreme expression of highest achievement in both poetry and astronomy ever met in one person. No absolutely inspired poet was ever a truly eminent astronomer. No astronomer of large achievement was ever a creator of inspired poetry. The astronomer knows himself for an astronomer. He never dreams that he is a great poet, or if he does, he is mistaken. The scientist of world eminence will never attempt anything in poetics of a pre-eminent nature. The true poet will know always that he cannot achieve any valuable result in science unless it be in the poetic way. No doubt Goethe was the father of the science of morphology. It was a happy inspiration. In the same way, Emerson suggested the law of evolution before Darwin enunciated his conclusions in biology. Both these poets were inspired men. Their achievements in the scientific fields were, in the final analysis, inspirational rather than intellectual. The poet may perceive some subtle phase of a scientific subject which the pure scientist had not observed, for sometimes he catches wonderful treasures of truth in the drag-net of his imagination.

Who can doubt that the erudite Copernicus realized with a poet's soul the far-reaching interest of his research. What a riot of emotion must have surged through his being when, having followed his game to its final lair, he discovered a new system of the heavens. How Newton must have thrilled to the first gleam of the universal law he enunciated. What wonder if he was so moved when the result of his computation transpired that an assistant had to bring the calculation to its obvious conclusion. His mathematics was to him, as to all the greater astronomers, only a feathered quill drawn from the wing of his imagination—that wing of inspiration with which he soared at the last to the mountain of his achievement.

The influence in the astronomic field of poetry and the poetic temperament is not fanciful, but entirely real and legitimate, revealing a higher value and significance than the cold intellectual processes could ever discover in the science of the skies. The telescopic eye is the supreme instrument of the practical astronomer, and its medium of activity is the light, yet without the kindly

ministrations of the veiling night, the most conspicuous thing about the eye is its myopia—its pitiable limitations. Except for what he learns by looking from the sheltering shadow of the earth, the astronomer would know little of the heavens.

Imagine the mighty hunter in the mountains of Elim, the builder of Babel, or the shepherd of Shinar, standing under the patient stars and wondering what it all meant, How awful that solemnity which first dawned upon him when he realised the silent, solemn grandeur of the night! What unspoiled wonder and humility in the presence of the incomprehensible! How his imagination would soar in the wide, free skies before its wings were clipt by the assumptions of dogma with its psychological complexes, its deplorable tie-up of reason, its paralysis of imagination, its fatal inhibition of universal science and poetry.

Had we not had the assistance of the night in our fuller exploration of the heavens, we should know now almost as little of astronomy as did the first Chaldean sage who looked into the sky, for little progress could have been made in conditions of continuous day. Only in the poetic mood does the astronomer adequately realize the scientific import of the night. Consider this local darkness, this spindle of invisibility, this slender needle of shadow that veils the nearer lights, but rolls up the curtain and reveals the drama of the stars. It is the apex of a cone of light based in the sun, intersected by the earth, then turning into an arm of uncanny shade that whirls around the sky and sweeps sometimes across the moon and far beyond, but never reaches the nearest vagabond that tramps along the zodiac.

The astronomer-poet realizes that every other planet and satellite has its own dark spindle of night. He needs but little mathematics to show him that Jupiter's shadow reaches approximately seventy-five million miles into space, frequently eclipsing his moons; that these moons throw shadows which transit the disk of Jove so that we can see these transits and eclipses almost any summer night when we feel disposed to look through a small telescope. Consider the night-spindle of the moon. When the earth's needle of night strikes our satellite, and we have an eclipse of the moon, then the shadow of the moon becomes a shadow within a shadow; but when the shadow of the moon is thrown directly

towards the earth, if it be long enough to reach us we have a total eclipse of the sun, if it falls short, we have an annular solar eclipse. So every planet and every moon has its spindle of darkness swinging around the sky.

Without this earth night, there could be no considerable science of astronomy as compared with that august body of truth which lies in so many ways at the foundation of our civilization. We should have the merest glimpse of Venus or Jupiter on those rare occasions when the day conditions were particularly favourable; a rare comet brighter than the light; a mysterious meteor flaming across the sky sometimes with crackling sound; we might even hear the crepitation of the aurora, but how should we know what caused the sound? We should see the moon by day at times, and when she passed over the face of the sun, we might know enough to say somewhat fearfully, "There is an eclipse of the sun."

Under such conditions, we should be blind with excess of light. Our astronomic sky would be "dark amid the blaze of noon." We should know little of the planets and less of the stars. The galaxy, the star-clusters, the nebulae, the binaries, the moons of Jupiter and their significance as to the speed of light, would all be to us unknown. How should we ever have known Ptolemy, or Copernicus, or Kepler or Einstein? Benighted in our poverty of night, all blind in a perpetual day, we should have been astronomical bankrupts, poets stranded in a morass of light, we should have been moved to implore:

> Come, gentle Sister with the starry eyes,
> With sable finger, open to our sight
> Those fields of unimaginable skies—
> Your vast demesne. Come, gentle Sister Night.
>
> Come in the silence. Let us hear afar
> The tramp of Time's retreat diminished long,
> Till night and quiet light and music are,
> And in our hearts is universal song.

Did Blanco White see the whole picture when he wrote:

> "Who could have thought such darkness lay revealed
> Within thy beams, O Sun! or who could find,
> Whilst flower and leaf and insect stood revealed,
> That to such countless orbs thou mad'st us blind?'

It is clear that in all these interesting sentiments and satisfactions, the astronomer has an ardent associate in the poet. The astronomer proves his poetic instinct by the fact of his achievement. Like him, the poet abates his interest in the proximate so that he may investigate the unknown and the remote. He sets himself, like the astronomer, as far as common interests are concerned, in an environment of shadow. In relation to all those other interests that absorb the community, and in which they insist upon the glare of noon, he must have night. He preens the wings of his imagination in the cloister of his soul, for only thus can he rise and soar into the empyrean of his thought. He darkens earth interests to a state of astronomic night; then the stars of the enlightened deep reveal to him as to the astronomer the invisible law out of the awed silences of their eternal habitation.

The astronomer, like the artist, the poet and the saint, in proportion to the ardour of his quest, will renounce materialities and dwell in the boundless universe. The measure of this renunciation is the only evidence of his authenticity as an astronomer, artist, poet, or saint, whichever he may be. No artist will reach to highest achievement unless he too give wing to wonder in that field that has no boundaries. Imitation, of which convention is twin sister, is to the poet and the artist, what dogma is to the saint, a paralyzing complex. As the astronomer's eye needs the protecting limitations of the night, so also do our intellectual and spiritual powers need to inhitit all proximate interests if we are to exercise them in a fuller devotion to teleological truth, whether it be in the field of poetry, art, religion, or the wonders of the sky, for darkness is the minister of light.

That sublime need which calls the prophet in all ages to the mountain—Horeb, Sinai, Carmel, Hermon—leads the astronomer to his observation mountain, the lofty, lonely place of silent thought, where his environment is earth-diminished and heaven-enlarged. He holds his sensitive-plate face-to-heaven for hours, and gets results beyond those achieved with the mightiest telescope. All the while the sensitive-plate of his own soul is impressed with the amplitude and serenity of the night. He is a citizen of the skies, but he works in camera.

The astronomer's devotion to his task must not be fitful if

he would obtain substantial results. He must make darkness his habitation. He must be a dweller in the spacious night. The astronomer does his best work while in exile. So did Victor Hugo, Wagner, Dante and St. John. What is an observatory but a place of exile? Were not Tycho Brahe and Kepler exiles in their island observatory at Uraniburg? What else were Herschel and Gill at the Cape? Or Lowell at Flagstaff? Or Pickering on the slopes of the Andes? Or those who have distinguished themselves at Mount Hamilton, and Mount Wilson? Or our own astronomers on their little island mountain near Victoria? While we envy all these their views of the fire-painted sunsets we remember that they are life-consecrated to science. The astronomer must be wrapped in darkness and lifted above the smoke and heat of cities and the dust of towns. Virtually, he must be as far as possible from civilization.

Even these astronomers who live in cities are somewhat austere in their habits. They are never known as addicts of the cabaret. They avoid the races. They are not often seen at functions. They live in almost eremitic retreat and dwell in "worlds more wide."

Both the astronomer and the poet perceive unseen laws of government and life in the silent and mysterious movements of nature. They are seers, and exercise the predictive faculty. Of all the prophet's functions, this is the least characteristic of his office. This is true also of the astronomer and the poet. But the masses still regard the prophet as one who foretells events, and the astronomer as one who predicts eclipses.

Seership or vision is common to all who are deservedly eminent. The very word astronomy suggests law. The student of star-law recognizes everywhere the reign of order, and in a certain sense, astronomy carries the quest of law to its farthest limits. The astronomer explores the most distant frontiers of space in his search of law. It is his passion. It is not enough that Laplace enunciated the nebular hypothesis and the world in general accepted it as final. The astronomer still held to his quest, so that we have theories as new as yesterday to explain the origin of the universes. What if Newton did, with apparent finality, demonstrate the law of universal gravitation, or Euclid lay down the

principles of geometric procedure, the astronomer remained in his enquiry room, the universe, and demonstrated the inadequacy of both by showing that when a body moves in space, other systems of geometry with new laws and dimensions are involved.

Like all other scientists, the astronomer is always on the brink of new vistas, at the portals of new eras, alert for the discovery of new laws, and, if the intuition of the poet be not more rapid in action, he is the first to discover them. Even in the arena of the sky, the inspired poet sometimes precedes the astronomer, as when the author of Job writes:

"He hangeth the earth upon nothing."

If the astronomer seem to lead the poet into new fields of discovery, it is sometimes only a seeming, for, as we have endeavoured to show, the astronomers best known to the world are themselves true poets and prophets, and it is the seer faculty in the astronomer-poet which prompts him to take that final leap which brings him suddenly to his hypothesis.

It is true that this faculty of vision is common to all highly developed souls in every field of life. It is a prerequisite of greatness. What physician of experience has not admired the precision and rapidity with which the eminent diagnostician determines conditions in a difficult case. He diagnoses his case accurately, and with a swiftness and decision that reminds one of the lion's leap. This decisive quality marks every man or woman who is super-eminent in fields of art. It is the final test of the authentic poet. The soul in tune with universal law has a power almost terrifying, for he has voluntary control of a portion of universal energy. He can determine at will in what direction it shall become kinetic, demonstrate its possibilities, realize its powers and actualize his dream.

The poet knows as well as the astronomer, and by a more immediate method, that the ocean runs singing up its shores in obedience to a mute Omnipotence, and as Tennyson says:

"If He thunder by law
The thunder is yet His voice."*

*The Higher Pantheism.

Concluded next issue.

THE ORBITS OF THE SPECTROSCOPIC COMPONENTS OF BOSS 4622.

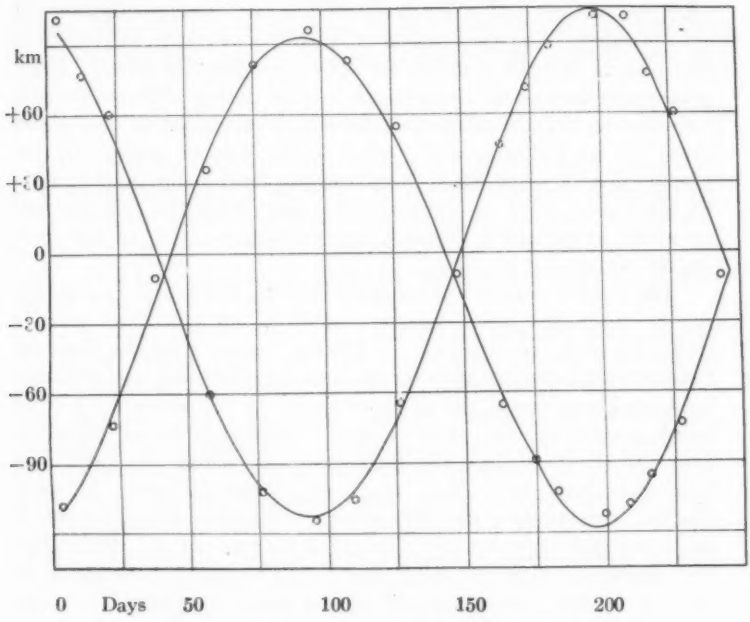
By W. E. Harper

THIS star (1900 $\alpha = 18h\ 13.0m$, $\delta = +56° 34'$, type F0, visual magnitude 6.41), was discovered to be a spectroscopic binary from the first plate made of it by the writer in July 1919, as the spectra of both components appeared upon the plate. Eight plates were secured that year, twenty-seven during 1920 and twenty-five during 1921, making sixty in all. Forty-eight of the plates show the lines double and twelve show them as single. Of the twelve showing single lines, three were not used in the investigation as the lines were fuzzy, due as later seen from the observations occurring at phases when only partial superposition of the lines would occur.

The component spectra are quite similar and consist, in addition to the hydrogen series, of the numerous metallic lines usually occurring in F-type spectra. It cannot be said that the lines are fuzzy in character and poor for measurement but they are certainly far from being sharp, and as the majority of the plates are a little underexposed for the most accurate measurement the probable errors which have been determined for the plates are large, but not surprisingly so. There is a very slight difference between the two components, and the stronger, designated component I, has a probable error for one plate of ± 4.2 km. per sec., while that for component II is ± 4.6 km. per sec. Fortunately the range in velocity is large, being over 200 km. in each component, and thus the probable errors of the elements are satisfactorily small.

Considerable time was spent obtaining the period. Where the lines are nearly equal in intensity it is hard to distinguish the components, and the difficulty is accentuated when you have a host of lines, each set with a wide range of displacements, crowded upon each other in the low dispersion of a single prism which was used throughout. The first period suggested was a 2-day one, as it seemed that the spectra alternated on consecutive days on the plates of the first year. For some reason this suggested period

was dropped, probably because the main series in 1920 suggested another. These observations were taken in a leisurely way,—just when the writer was observing, and when plotted consecutively on cross section paper seemed to indicate a 72-day period. This was felt to be the period without a doubt and as there were a few gaps in the curve, it was decided to wait the necessary time so as



Velocity Curve of Boss 4622, with Grouped Observations.

to fill them up. Fortunately these, when obtained, fell so much off the curve that the period of 72 days was questioned. It was then found that as good a curve could be obtained by using a period greater than the even day by 1/72 day. The 1921 series, however, could not be brought into complete accord and finally a period of 2.0476 days was found, which satisfied perfectly the observations of all three years. No attempt has been made to

improve on this value by incorporating the period in the least squares solution.

The following table shows the preliminary elements adopted and their final values resulting from a least-squares solution. The solution lessened the sum of the squares of the residuals for the 28 normal places into which the observations were grouped by about 26 per cent. The accompanying graph represents the final elements and the observations as grouped, the broken circles representing those of component II.

ELEMENTS OF ORBIT

Element		Preliminary	Final
Period	P	2.0476 days	2.0476 days
Eccentricity	e	.02	.039 ± .008
Longitude of periastron	ω_1	195°	195°.10 ± 0°.52
Longitude of periastron	ω_2	15°	15°.10 ± 0°.52
Velocity of system	γ	−6.80 km	−8.51 ± 0.63 km
Semi-amplitude of range	K_1	103.0 km	105.09 km ±1,10 km
Semi-amplitude of range	K_2	108.7 km	108.12 km ±1.18 km
Periastron passage	T	J.D. 2,422,147.630	J.D. 2,422,147.630
Projection semi-major axis	$a_1 \sin i$		2,956,600 km
Projection semi-major axis	$a_2 \sin i$		3,041,900 km
Mass componentI	$m_1 \sin^3 i$		1.043 ⊙
Mass component II	$m_2 \sin^3 i$		1.013 ⊙

Though our empirical curves connecting line intensities with absolute magnitudes are as yet far from complete, yet an inspection of the lines would suggest a preliminary value in the neighbourhood of +1.5 for the combined absolute magnitude, in which case the parallax would be 0″.016. This of course must not be considered as definite.

Dominion Astrophysical Observatory,
Victoria, B.C.

Nov. 12, 1921.

ORBIT OF THE SPECTROSCOPIC BINARY BOSS 5442

By Reynold K. Young

BOSS 5442, R.A. (1900) 21h 04.4m, Dec. +29° 48′, mag. 5.6, type A0, was discovered to be a spectroscopic binary from plates taken in 1918. The spectrum, given as type A0, is better classified as B8. There are present the K line of calcium which is sharp and narrow, the hydrogen series of which both $H\delta$ and $H\gamma$ are good, a fine 4481 and 4472 and the two silicon lines 4128 and 4131. The iron line 4549 and some others are present on a few plates, but are very weak and of little use for radial velocity determinations.

Observation of the star was begun in July 1920, with a view to obtaining the orbit, and between that date and August, 1921 forty-nine spectrograms were secured.

It proved a difficult task to find the period of the star. It is not certain that the observations can be represented by simple elliptic motion. There can be no doubt of the existence of the period 3.3137 days, and on this basis the observations have been grouped into eleven normal places and orbital elements determined from them. The accompanying curve shows how the period chosen harmonizes the velocities. The early observations are shown by a large filled circle, the 1919 observations by a small circle and those of 1920 by an open circle. The approximate elements are:

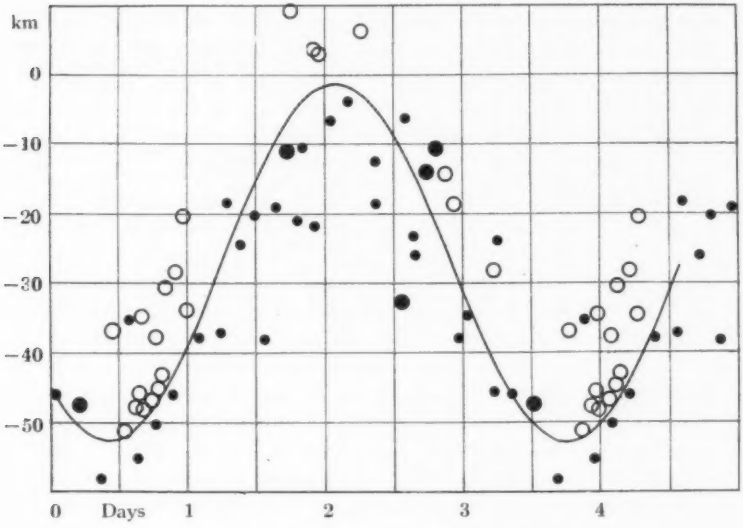
Period	P	= 3.3137 days
Eccentricity	e	= 0.0
Periastron	T	= J.D. 2,422,521.230
Semi-amplitude	K	= 26 km.
Velocity of system	γ	= −26.8 km.

$a \sin i = 1{,}185{,}000$ km.

$$\frac{m_1^3 \sin^3 i}{(m + m_1)^2} = .0060 \odot$$

It has not seemed necessary to perform the labour of a least-squares solution in order to render the agreement between the

normal places and the representation by the elements the best possible, because the elements are obviously approximate. The disposition of the normal places suggest the blending effect of a secondary component, unresolved but affecting the measures. It is well known that the general tendency of an unresolved component is to sharpen the curve at minimum and maximum. The plates were re-examined to detect the presence of the secondary but no



Rad'al Velocity Curve of Boss 5442 showing the individual observations.

certain trace of it was found. In estimating the value of K, however, the curve was drawn through the maximum and minimum velocities tacitly assuming that the measures were affected by an unseen secondary.

Certain features of the plot of the individual observations are worthy of note. While all the observations conform in a general way to the adopted period, yet the range of the discordance is very large, much larger than to be expected from the character of the lines. The 1920 observations, most of which were taken on

two nights, are distinctly above the mean for the 1919 observations and, moreover, they indicate a slightly larger range. These features recall the behaviour of the binary 12 Lacertae. It was shown that the latter binary has a variable amplitude and that succeeding revolutions of the star did not always produce the same shaped curve. If such is the case with Boss 5442 it would be an exceedingly difficult task to establish the fact with certainty, for the period being over three days it is impossible to obtain a run of plates to define adequately the curve in one revolution. We have searched for a secondary period but have not found any except the long period which might account for the difference between the 1919 and 1920 observations.

Dominion Astrophysical Observatory,
Victoria, B.C.

November, 1921.

ON THE ADJUSTMENT OF EQUATORIAL TELESCOPES

By Howard Grubb

Concluded from the December Issue

All the remarks made on adjustment 2 apply equally to this, and a little consideration will show that even if considerably out of adjustment in this last direction the error could not have affected the accuracy of the observation made for No. 2, provided the star in No. 2 adjustment was close or near to the Equator.

4 and 5. *Zero of Declination Circle and Inclination of Polar Axis.*—I take these two adjustments together because the one pair of observations determines the error of both. I choose a star (again preferably as near as possible to Meridian, but higher than Equator, near to Zenith), some star whose R.A. and declination can be found in the *Nautical Almanac* or other Catalogue; set telescope on it carefully, paying more attention this time to the setting in declination than the setting in R.A. Having satisfied myself of the setting in declination, telescope being at E. of Pier, I read declination circle. Again set with telescope W. of pier and read declination circle; call first reading A and second B.

If there be no difference in the readings A and B the declination circle has no zero error. If there be a difference (which is most likely) the declination circle should be moved round (or its verniers moved) by a quantity equal to *half the difference*, and it will then be found to read the same declination for the same star, whether telescope be at E. or W. of pier: *this corrects No. 4. Now to correct No. 5.* The reading A or B, if they be equal (or A plus B divided by 2 if they be unequal), is the declination of that star as measured by the instrument *with its present inclination* of polar axis. Look to Catalogue, and the observed declination as above should equal the declination as given in Catalogue, plus or minus the refraction according as the star is south or north of the zenith. If the declination be a north declination and reading by instrument too high, the polar axis is too much inclined to horizon, and *vice versa*. The best practical way to adjust this is; if it be N. declination, set the

declination circle of the telescope to read the declination of the star, as given in Catalogue, plus the refraction, and then if telescope is found to point too high or too low, adjust polar axis by whatever screws are supplied for the purpose till the star reaches the centre of the field. To find out the quantity to be added for refraction; *the refraction tables give refraction for any given altitude*, and when the star is on the Meridian its altitude is equal to the co-latitude of place, plus declination if it be N. declination, or minus declination if it be S. declination. If star be chosen near Zenith the refraction may be neglected.

Another method of working adjustments 4 and 5 is as follows, but this I have never tried myself. Place the telescope vertically over a vessel of mercury, pointing downwards, and make the reflected image of cross-wires coincide with the cross-wires themselves, then the telescope points exactly to the nadir and the declination circle should read 180° plus latitude; repeat this at the other side of the pier, and adjust the circle as directed in the case of a star. Then set the circle to 180° plus latitude and raise or lower the polar axis until the cross-wires and image coincide and the axis is right. In the case of a reflecting telescope point it to the Zenith and put a level on a straight edge across the speculum in the Meridian. For the Nadir observation it is necessary to throw light down the tube; the simplest way is to have a small blank eye-piece (to be put over the real one) furnished with a small piece of glass, which can be given any inclination to the horizon so as to reflect daylight or artificial light down the tube.

Dr. Dreyer, of Armagh, tells me he has used this latter plan in the case of Lord Rosse's 3-ft. reflector.

6. *To Adjust Polar Axis into Meridian.*—This is generally a troublesome observation to effect with precision, because it necessitates the observation of stars off the Meridian, in which case the influence of refraction must be found by calculation; of course to a practical astronomer this is no trouble, but to an amateur, or indeed any one (when, as is often the case, there are plenty of clouds drifting about so that the operation must be done quickly or not at all), a method of making this adjustment without the necessity of estimating the refraction is generally to be preferred.

If there were no refractions to trouble us, and that all the

preceding adjustments had been made, leaving only this one to be effected (the reading of the R.A. circle is not mixed up in this observation), it is evident that all that would be necessary would be to set on any known star some hours off Meridian (if possible at an hour angle of six hours), and if the declination of this star did not read rightly according to the Catalogue to *make it read rightly* by moving the whole instrument in azimuth. As this is the only adjustment not perfected before, it is clear that this would be the correct course. This plan suffices for very small instruments, but for large, and where refraction must be allowed for, I take two stars, each about an equal hour angle, one in E. and one to W. of Meridian and of about equal declinations, and I take alternate observations. When I find that the excess of the actual reading of declination over the Catalogue reading is equal with each star, I consider the adjustment to be correct and I check this still further by taking an observation of the polar star after the next adjustment.

7. *To adjust R.A. Circle.*—For this adjustment either a level on declination axis, a mercury trough, or a knowledge of exact sidereal time is necessary. From Catalogue ascertain the exact R.A. of any star (preferably near Equator at the time of observation as the apparent motion is most rapid). The reading of R.A. circle when telescope is pointed to that star should be sidereal time, minus R.A. of star. The best practical way of making this observation is as follows:—I subtract the R.A. as found in Catalogue from actual time shown by sidereal clock, not at that moment, but from some definite minute a little in advance of what the clock shows (to give time for setting telescope), I now set telescope on star and start equatorial clock and see that it keeps star in centre of field, the moment the clock points to that minute for which I made my calculation I stop equatorial clock and read R.A. circle, if it is not correct I loosen nuts holding circle and move round circle till it reads correctly. If the telescope be provided with a level to declination axis it is not necessary even to have sidereal time, for if the declination axis be levelled by the spirit bubble and the R.A. circle be turned round till it reads XII or XXIV, this last adjustment is completed, or the verticality of telescope

and consequent horizontality of dec. axis may be found by using a mercury trough as before.

I go over all these adjustments a second time and then check the azimuth position by taking an observation of the Pole star, which, moving as it does in a very small circle round Pole, shows a very large error in hour angle for any given error in azimuth of polar axis. If necessary I adjust the azimuth once more till R.A. circle reads correctly on Pole star. If this observation of Pole star be made when it is crossing or nearly crossing the Meridian, either in its upper or lower transit, refraction will only affect the declination readings and not the R.A. readings.

Respecting the means of effecting these various adjustments it is not easy to be precise, for different makers supply more or less adjusting arrangements, nor do they all act in the same way.

For the 1st adjustment.—The wire plate is made generally adjustable as described.

For the 2nd Adjustment mentioned above, provision is rarely, if ever made, and if necessary it must be done as I said by a liner of paper or card.

For the 3rd Adjustment provision is also rarely made. In my large instruments I make the small bearings of declination axis on a slide and have opposing screws for this adjustment.

For the 4th Adjustment.—If error be large the whole circle must be turned round on its axis and again clamped by whatever provision is left for the purpose by the maker. If the quantity be small, as it is likely, the vernier will probably move a sufficient quantity if its screw be loosened.

For the 5th Adjustment.—In Messrs. Cooke's instruments and in my portable forms this adjustment is made by loosening the screws which fasten the polar axis frame to head of pillar, and working the right and left-handed screws at south end of polar frame. In my standard form this adjustment is effected in the frame between the wedge-shape casting and top plate by screws specially provided for the purpose.

For the 6th Adjustment.—In the pillar (portable form) and also in the standard instruments, provision is made for this adjustment by a right and left-handed screw.

For the 7th Adjustment.—As in the case of No. 4, if errors be large

the circle must be loosened on axis and turned round; if error be small the amount of play left in the screw holes of vernier may be sufficient.

Having now described the *rationale* of the various steps of the process, I proceed to put the instructions into a concise form, but as the method of proceeding, which would be suitable for a large first-class equatorial would be absurdly complex for adjusting small portable instruments, and on the other hand, instructions sufficiently precise for adjusting small portable instruments would be quite insufficient for other larger sizes, I give three different sets of instructions.

A I consider sufficient for the largest and most perfect instruments. *B* is suitable for the small sizes of equatoreals, say for 4-inches and over, while *C* is only applicable for very small size equatorials or those of Portable form, which are not expected to keep in permanent adjustment.

A.—Having placed the instrument in approximate position.

1. Adjust finder to point to same object as great telescope.

2. Observe star near Meridian and Equator, telescope being to E. of pier, clamped, and clock going. At any certain minute by watch, stop or disconnect equatorial clock and read R.A. circle; call this A. Repeat this observation with telescope W. of pier, and stoppng clock at any other minute, read R.A. circle again; call this B. If difference of reading A and B, plus or minus 12 hours, be equal to difference of time of observation as shown by watch, telescope is at right angles to declination axis. If the difference of reading A and B be greater than difference of time by watch, the angle A D C is too large, and *vice versa:* for estimation of quantity see above.

3. Having made this right, repeat above observation, using a star near pole; any error found by this observation must be between declination and polar axis, if No. 1 has been properly corrected.

4. Choose any well-known star near Meridian and N. of Equator, say not less than 30° or 40° N. declination; set telescope on this, paying particular attention to the readings of declination circle (telescope being E. of pier), call this A. Repeat this with telescope W. of pier, call this B. If A equals B there is no Zero error of declination circle, if A be greater or less than B, the declina-

tion circle has a Zero error equal to the difference A minus B divided by 2; set this and try this pair of observations over again till the declination of every star reads a similar quantity with telescope at E. and W. of pier.

5. Now set declination circle to read whatever declination is given in Catalogue for that star, plus the refraction for its altitude (equal to co-latitude plus N. declination), and if the star is not in centre of field, alter inclination of polar axis till it is.

6. Choose two stars of about equal declination (preferably high stars) E. and W. of Meridian, each being from three to six hours from Meridian. Set declination circle to read the proper declination for that star which is to W., omitting any correction for refraction. If star cannot be brought into centre of field with that declination setting, alter azimuth screw till it does. Now turn to star at E., set declination circle to its proper reading for it; if it cannot be brought into centre of field with that declination reading, turn azimuth screw till it is in centre again, *counting the number in turns;* now turn back azimuth screw half that quantity and the instrument should be in adjustment. This may be checked by taking the actual readings for declination circle for both E. and W. stars, and if about equal altitude the errors in each case (which are due to refraction) should be equal.

7. If there be a level to declination axis, level axis by it and set circle to read XXIV or XII. If there be no level, turn telescope on any star near Meridian and if the circle does not read correctly *i.e.*, sidereal time minus R.A. of star, cause it to do so by altering it or its vernier.

Lastly, turn on pole star, at its upper or lower transit, setting circle to the proper R.A. or declination. If pole star be not in centre of field, bring it up by altering azimuth motion of telescope a very small quantity.

B—Less accurate set of adjustments.

1. Adjust finder.
2, 3. Omit altogether if telescope be from any good maker.
4. Same as A.
5. Same as A.
6. Same as A.
7. Same as A.

C.—Least accurate set of adjustments.

1. Adjust finder.

2, 3. Omit altogether.

4, 5. Same as A.

6. Set telescope to declination of any star a few hours E. and W. of Meridian, turn telescope on star, if it is not possible to get it into centre of field by R.A. motion alter azimuth till it is.

7. Same as A.

Adjustment of Object Glasses in their Tubes.—It is generally taken for granted that this adjustment is made before it leaves the maker's hands, but it often happens that after a journey the counter cell into which the objective screws is found to be slightly displaced, and the objective is used, perhaps for years, in an imperfect state of adjustment in consequence of its owner not knowing how to detect any want of adjustment or correct it when detected.

To Detect want of Adjustment.—Direct telescope to any convenient star. If the telescope be of large aperture it is not well to use too large a star, and in every case I like to make the final adjustment on a small star; one just sufficiently brilliant to see one or two rings round it with a high power is best.

In commencing also I use a low power, but as the adjustment gets more perfect I use higher powers.

Get star fairly in centre of field and focus, observe if the light round star be symmetrical. Whether it be scattered light as it will be with low power and bad atmosphere, or in the form of rings more or less condensed as it will be on good nights, with a high power, it should be *symmetrical.* If it appears symmetrical try a higher power, and if necessary a smaller star.

I find it assists appreciation of the symmetry, or want of symmetry of the image, to keep the focussing button moving in and out of focus both ways. If under any power or on any star in centre of field the image appears unsymmetrical, the object glass requires adjustment. In every case that side of the objective at which *most flare* is perceived is *too far* from the eye-piece.

To Adjust.—Loosen all the screws which hold the counter-cell to tube, leave them just so tight as to hold the counter-cell wherever it be moved to, but not so tight as to prevent it being moved at all; now with a piece of wood like a small mallet tap the flange

of the cell or counter-cell towards eye-piece at that side at which most flare is seen; no idea can be given of how much to move it, but a very small quantity will in most cases suffice, 100th of an inch makes a very sensible difference in a moderate sized objective.

It is very unlikely that the first attempt will make it right, but by repeated trials and tappings a satisfactory position will probably be found, and then the screws may be again tightened. It is very possible that this very tightening of the screws will again disturb the adjustment and it may be necessary to go back on it.

Fraunhofer constructed a small apparatus for testing whether the axis of the object glass passes through the centre of the eye-piece. It consists of a small collimator in a tube which is fastened to a small plate with three screws. Place this on the object glass, two of the screws touching the rim of the cell, and point to centre of eye-piece by the three screws, then carry the apparatus round the circumference and see if remains pointed to centre of eye-piece.

It may be asked why do not makers supply adjusting screws for such a delicate adjustment? I have done so in some cases, but except for very large objectives I did not find them to work well. It would appear that in the case of using screws the cell is liable to be slightly strained before it begins to move to its new position, but the very fact of the blow of the mallet shaking the whole cell causes it to jump promptly into its new position without strain. Of course in the case of very large objectives such as the Vienna, in which the glass and cell weighed some 250 lbs., a mallet to have any effect should be of considerable weight and no one would like to have to use such a weapon in the vininity of a £4,000 glass, and here I did apply special adjusting apparatus. If it so happens that with *any* adjustment of the glass as above described symmetry is not obtainable, other matters should be looked to. It is possible (as I have sometimes found) that the eye-tube is not in line with axis of telescope. The best way to test this is to draw out slip-tube which carries eye-piece and insert in inner end a card-board disc with a small, say $\frac{1}{10}$th inch central hole. Now place it back again and insert a high-power eye-piece, or better still, the eye-stop only of such in its ordinary place at outer end of slip tube. Now look through objective at eye-piece, and travel eye about till you see light through *both* holes, then your eye *is*

in axis of eye-tube, and this should be the centre of objective, which you can readily test. If it be not, the eye-tube is not square in tube, and the telescope had better be returned to the maker for alteration.

If this eye-tube be found right, but image is still not symmetrical, something is probably wrong with the objective which is beyond the power of any one but the maker to attempt to rectify. I would however, desire to mention a few matters which may disturb this symmetry and cause what is really a good glass to be unduly condemned.

Temperature has a most extraordinary effect on the correction of an object glass. This is not the place to discuss this fully, but I may mention that an objective taken from a warm room to open air and inserted in its tube will, after a minute or so, begin to show *under correction* for spherical aberration, which will increase sometimes to an alarming extent, the maximum being reached at a time which will vary according to circumstances (I have known it to increase for over half an hour) and then gradually decrease till it once more assumes its normal state. Again, if tube be warmed by sun the image becomes quite unsymmetrical, the section of cone of rays being vertical outside focus and horizontal inside focus. If objective be put in warm and it warms the air inside tube the appearance is that of Fig. 3*a* outside focus and Fig. 3*b* inside. I mention this to prevent persons forming any judgment too hastily.

Personal Defects of Eye-sight.—Very few eyes are really symmetrical in themselves and the effect on the image in the telescope is very apparent.

My own eyes when examined by an oculist were considered to have very little want of symmetry, very little "*astigmatism*" as it is called, so little that a 70-inch focus cylindric lens corrects this; still this astigmatism is a great trouble to me in testing objectives,

When an objective is best for my own eyes I know it is not perfect, and in final trials I always make a practice of continually altering the position of my body as respects any given diameter of the objective. This astigmatism of the eyes, however, is only

apparent in using *low* powers, probably because a larger aperture of the crystalline lens is used in that case.

In all cases of want of symmetry of image in a telescope the cause can be localized by turning round successively each part of the apparatus: first say the objective glass, if the unsymmetrical figure remains in same position it is not the objective that is in fault—then the tube—then alter the position of body and so on. If, as I have often found, the unsymmetrical figure of image continues constant *through all these experiments*, it is probably due to layers of air of unequal refrangibility in tube. After a tube has been recently blackened on inside this is often seen very strongly, the vapour from the varnish accumulating at upper side and forming there a stratum of different density to the rest of the air in tube.

Adjustment of Mirrors in Reflecting Telescopes.—Whether the telescope be of the form of the Newtonian, Cassegrain or Gregorian, the same system of adjustment is available. Take out the lens of the eye-piece, leaving only an eye-stop for the purpose of centering the eye in the tube. On placing the eye at this hole an image of the large mirror will be seen reflected in the small mirror, probably not central. By the three screws at back of small mirror adjust it till the rim on cell of large mirror appears to be concentric with the rim of the small. Up to this point of the process the large mirror may, if desired, remain covered; now uncover large mirror and an image of the small mirror will be seen in the centre of the image of the large mirror as reflected on the small. If this be not central, make it so by adjustment of the three screws at back of *large* mirror. When making this last adjustment let the telescope be nearly vertical. If a greater degree of accuracy be aimed at than is attainable by above process it is best to use the collimating arrangements of Dr. Stoney.

Referring to Fig. 4.—The point that is really essential is that the axis of the eye-piece tube (and consequently optical axis of eye-piece) should coincide with the axis *d e* of a central pencil from the great mirror. It is not by any means necessary that the angle *c d e* should be 90°. Dr. Stoney mounts his eye-tube, *not* rigidly to side of tube, but on a plate which is adjustable thereon

by three screws so that he can alter the direction of the axis of the eye-tube.

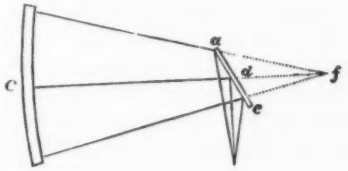


Fig. 4.

To test the adjustment the eye-piece is removed and a tube is inserted in its place, carrying an achromatic lens of as large a size as will fit the tube, and at a certain distance behind this lens an eye-piece in focus of which is placed a pair of platinum wires nearly touching, but insulated from, one another, and mounted in an insulated ring. These are connected to a small induction coil and a spark is caused to pass between these points.

The distance between spark and achromatic lens is so arranged that the rays of light from spark after reflection from small mirror to large are *normal* to surface of mirror, and are, therefore, returned again with the same vergency, and after passing a second time through lens, form *an image* of the spark in same plane as spark itself, and consequently visible through the eye-piece simultaneously with the spark. If all be in perfect adjustment the image of spark should be found superimposed on spark itself. If adjustment has been made nearly right before, a very little turn to screws which attach the eye-piece to side of tube makes all right.

Dr. Stoney states that the gain in definition by this extra fine adjustment is so great as to induce him to make a fresh adjustment for almost every new object he turns the telescope to, particularly as a few seconds suffice for that operation.

Sir J. Herschel used a small collimator telescope, mounted inside tube and pointing directly at great mirror. This was supplied with illuminated cross-lines which were so placed that when the mirrors were in adjustment the cross-lines were visible in centre of field of eye-piece; any want of adjustment could thus at any moment be detected.

In Cassegrain and Gregorian telescopes the exact position and size of eye-stop is very important; *to adjust this*, screw in eye-piece and uncover mirrors, now take a small hand magnifier, say about 1½-inch focus, and with it examine the eye-stop, an image of the small mirror will be found just at this stop.

1st.—If this image is not central with stop it should be made so by loosening the screw which holds eye-stop in position and pushing it about till it is concentric with image.

2nd.—The stop should then appear just such a size as to admit of the whole of the small mirror being seen, but no sky-light around it.

3rd.—To test if stops be at right distances from eye-lens, pass the eye (and magnifying lens) back and forward so as to view the image at a considerable angle as well as directly. If image be (as it ought to be) in plane of eye-stops, it will appear to remain stationary as regards the stop, no matter what angle it is viewed from. If image appears to move to right when eye is placed to left, and to left when eye is placed to right, the stop is too far in or too near eye-lens and *vice versa*. In no position, whether the stops be viewed directly at any angle, should any sky-light be visible round image of small mirror. Theoretically the eye-stop should be placed a little inside the focus of images of small mirrors, in fact at image of *large* mirror as seen in small, but except in very large instruments the difference is not appreciable.

MEETINGS OF THE SOCIETY

AT VICTORIA

November 3, 1921.—The first regular meeting of the winter term was held in the auditorium of the Girls' Central School at 8 p.m.

Mr. L. A. Geuge, 534 Vancouver Street, Victoria, B.C.; Mr. W. H. Christie, Hollywood Crescent, Victoria, B.C., and Mr. R. G. Miller, 2047 Chaucer Street, Oak Bay, Victoria, B.C. were elected members of the Society.

Dr. J. S. Plaskett addressed the meeting upon the subject:—"The Dimensions of the stars." He began by explaining why a knowledge of the dimensions of the stars was essential in astronomical problems. It being not only necessary to know the size and mass of the stars, as well as their positions, motions and physical and chemical condition for their bearing on the constitution of the universe, but the dimensions of these bodies formed a crucial test between two theories of stellar evolution.

These theories were briefly sketched, the older theory stating that the stars developed from the nebulae beginning with the hottest B-type blue stars of small density and proceeding through white, yellow and red stars to extinction, constantly decreasing temperature and diameter. The newer theory, on the contrary, though beginning with the nebula requires both an increasing and decreasing temperature and, after the nebula, the next stage is a very tenuous red star of enormous diameter—a "Giant" star. After passing through the maximum temperature of the blue type, the red stage is again reached although this time the star has a high density and small diameter—is a "dwarf" star. Evidently then a knowledge of the dimensions of the stars will show if there are both giants and dwarfs of the same type and how to differentiate between the two hypotheses. Much of the knowledge and many of the methods for obtaining the dimensions of the stars are due to Russell, (the founder of the newer theory) in search of evidence for or against this hypothesis.

Of the three factors—diameter, mass and density—any two will serve to determine completely, dimensions; and mass and diameter were chosen for treatment.

The masses of the stars can only be obtained from the attractive force between double stars, according to a relatively simple relation, the harmonic law, and when the distance apart of the components is expressed in terms of the distance of the earth from the sun and the period in years the mass of any double star system is the separation cubed divided by the period squared times the mass of the sun. Using this rule it was shown the average masses of the pairs in the relatively few giant stars was about ten times that of the sun and, in the pre-

ponderatingly large number of dwarfs, about twice that of the sun. The maximum known mass of any star is 19 times, and the minimum about 0.15 times, the sun. Making reasonable allowances, the masses of visual spectroscopic and eclipsing binaries are of the same order and, in general, the mass of the single component is not much different from the sun.

Of the other two factors—diameter and density—only methods of obtaining *diameters* of stars were discussed. The direct measurement of stellar diameters by the telescope is hopeless and the only way to get absolute values is by eclipsing binaries. The photometric orbit gives the inclination and the ratio of the diameters of the components to their separation, which, combined with the projected separation obtained by the spectroscopic orbit, enables actual diameters to be obtained. It is found that the diameters vary between 0.6 and 110 times the sun, while the densities lie between less than one-millionth and five times the density of the sun.

Russell and Eddington, by relatively simple methods have computed the apparent diameters of stars while an interferometer attached to the 100 inch telescope has enabled the apparent diameters of three stars—Betelgeuse, Antares and Arcturus—to be obtained. The measured values are intermediate between the two computed values and give confidence in the accuracy of the theoretical results. Using corrections from the measures, the apparent diameters of a number of typical stars have been computed, which, with the most probable parallaxes, enable the actual diameters to be obtained. These values probably approximately correct, lie between 155,000 miles for Barnard's Runaway Star, to 275,000,000 miles for Antares, clearly showing both giant and dwarf stars of the same spectral type and thus confirming the newer theory of stellar evolution.

A number of illustrative slides were projected upon the screen during the lecture, which was listened to with close attention by the audience, who enthusiastically endorsed a hearty vote of thanks to Dr. Plaskett for his highly entertaining and instructive address.

AUGUSTIN SYMONDS, *Secretary.*

AT WINNIPEG

November 9, 1921.—The Society met in Room 21, University Arts Building, the President, N. R. Wilson, in the chair. It was moved by Professor Warren, seconded by Mr. Bastin, that the President and the Secretary send a letter to Professor Kingston, congratulating him on his new position (in the Western University, London, Ontario) expressing the appreciation of the Society for his work in the past and regret that he has left, and wishing him success in his new surroundings.

Mr. Bastin gave a short talk on the Milky Way, explaining that the modern scientific belief is that the Milky Way is just what it appears to be, a vast ring of stars, our solar system being approximately in the centre of this ring, and the stars in the intervening space being really farther apart than those in the ring. Several interesting slides showed portions of the Milky Way as seen through a large telescope.

The lecture of the evening was given by Mr. H. B. Allan, whose subject was "The Moon." Mr. Allan explained the real cause of the outlines and the light and dark patches seen on the moon and popularly described in different ways. He proceeded to deal briefly with the phases, the inclination of the moon's orbit to the ecliptic and its especial bearing on eclipses, also the difference in altitude of the moon during the Summer and Winter.

This was followed by a detailed description of the moon's surface, the apparent absence of atmosphere, etc. Mr. Allan dealt with the real and supposed effects that the moon had on the earth, pointing out that most of the effects, such as weather conditions and other influences credited to the moon, were pure fiction, but that at the same time the moon served several very useful purposes, chiefly in connection with the tides and also as a subdivider of time. The difference between sidereal and synodic revolution was explained. Continuing Mr. Allan took each prominent surface detail, namely dark patches, mountain ranges, walled plains, lunar craters, rills, clefts and lunar rays, pointing them out on the slides, giving the dimensions of many of them and endeavouring to explain the causes of the formations based upon some of the most acceptable theories. In conclusion, the recent announcement of Prof. W. H. Pickering in regard to the changes on the moon's surface, particularly in the region of Eratosthenes, which he attributes to vegetable growth, was gone into, Mr. Allan expressing the opinion that much more remains to be done in the way of observation and more convincing proofs must be forthcoming before Prof. Pickering's assumptions can be readily accepted.

C. D. MULLER, *Secretary.*

AT TORONTO

November 15, 1921.—Mr. G. W. Bell, 406 Huron St., Toronto, and Mr. W. R. Watson, 117 North Beaconsfield St., Toronto were elected members.

The paper for the evening was given by Dr. A. D. Watson, a Past-President of the Society, who addressed the meeting upon the subject:—"Astronomy in a Poet's Life.' It is quite beyond the powers of the Recorder to adequately summarize the eloquent paper given by Dr. Watson, who showed that the poet and the astronomer had much in common. The influence of poetry in the astronomical field was not fanciful, but a reality; for the astronomer was a better astronomer if he possessed the imaginative mind of the poet, while the latter was a better writer if he was also an astronomer. Virgil, Shakespeare, and many of the great poets knew the astronomy of their day; and astronomers, when describing their discoveries, are indeed potential poets. Who can doubt but that the erudite Copernicus realized with the poet's soul the system of the heavens which he was the first to advance? The paper which was most heartily enjoyed by the members, was made the more interesting by Dr. Watson giving several selections of poetry, some of them being original.

Mr. J. A. Paterson, in a few remarks stated that no one was better fitted to speak upon such a theme, as the lecturer not only studied astronomy, but also wrote poetry. Several other members also expressed their appreciation of the interesting paper.

November 29, 1921.—Dr. Emma Connor, 249 Pinnacle St., Belleville, Ont., Mr. Charles Sankey, Sidney Cottage, Belleville, Ont., and Mr. Patrick Walker, 342 Victoria St., Toronto were elected members.

Mr. J. A. Paterson, K.C., M.A., a Past-President of the Society addressed the meeting upon the subject:—"Percival Lowell, his Life and Work."

To illustrate the man and his work, Mr. Paterson selected the following motto from Emerson: "Nothing great is ever achieved without enthusiasm." Percival Lowell was born in Boston, Mass., in 1855, and he graduated from Harvard in 1876, being considered a very brilliant mathematician. For a number of years he travelled in the East, and while there published his first book of poetry. Becoming interested in astronomy, and in the planet Mars in particular, he decided to follow up the work begun by Schiaparelli. Realizing that in order to see the markings upon the surface of the planet, incorrectly translated into English as "canals," that the site of the observatory was of vital importance, he spent several months travelling through France, Algiers, Switzerland, Mexico, South America and Southern United States, hunting for a suitable situation. Finally, he selected Flagstaff, Arizona, which is remarkable for the rarity of its atmosphere, and there built his observatory.

Scientific attainment and business ability were united in him in an unusual degree, and his genius was soon evident by the number of volumes on Mars which appeared in rapid succession.

The lecturer enumerated some twenty-five facts about the planet, observed by Lowell and his staff, and then gave Lowell's interpretation of them. The conclusion he reached is, that Mars is habitable, and that it has been established beyond a doubt that vegetation exists upon its surface. If there is a flora, then we may safely conclude that there is a fauna also, and that there must be on Mars those higher types of intelligence analogous to man. That we shall ever be able to communicate with them, is a question which Science to-day has no data to decide.

In conclusion, Mr. Paterson gave his own opinions upon the plurality of worlds.

December 13, 1921.—Mrs. J. B. Taylor, 81 Belhaven Road, Toronto; Mr. James Young, Meteorological Office, Bloor Street, Toronto; and Mr. Walter Cluxton, 62 St. George St., Toronto, were elected members.

The Librarian's report showed that 39 periodicals had been received during the month.

Mr. John Patterson, M.A., F.R.S.C., of the Meteorological Service, gave the lecture of the evening, speaking upon the subject of "Aerial Navigation." Mr. Patterson pointed out the importance of the work being done by the Canadian Air Force in patrolling the forest regions of Canada for the purpose of preventing fires. He mentioned two cases which occurred in Manitoba this year, one, in which a pilot from the Air Station of Victoria Beach, Lake Winnipeg, detected a fire in the distance, flew back to his base, and returned with a party of men and the necessary fire-fighting equipment, who had the fire out within forty-eight hours. On another occasion, the Air Force transported nine men to the scene

of the fire and maintained them there a week before it was extinguished. Every service of this kind is a saving to the Government of a very considerable amount of money, which justifies the expenditure in maintaining Air Force Stations at regular intervals across the Dominion. The lecturer mentioned another service which had come to his attention in B.C. The Geodetic Survey had been allotted two years to complete a certain triangulation in the mountains where the stations were difficult to establish. The Air Station at Vancouver came to their assistance, and flying from peak to peak, the surveyors photographed the mountains, and by thus finding out the best stations for observation allowed the work to be completed in a few weeks.

Mr. Patterson exhibited a set of the instruments used in Aerial navigation, and explained in detail their construction and use. They consist of: (1) a revolution counter, for determining the number of revolutions of the propeller per minute, (2) a compass, for use when flying above the clouds or in fog, (3) an inclinometer, to register the tilt of the plane, (4) a wind gauge, to record the velocity of the machine with respect to the wind, and (5) an altmeter, which gives the height of the flier above sea level. The lecturer explained the limitiations of the above mentioned instruments, and the problems thus introduced. As a flier cannot accurately determine the direction and velocity of the wind, he does not know his true course and speed. The altmeter, is of comparatively little use in undulating countries as it does not show the height above the ground. This is an important field for research, as at present there are no instruments to record the precise information desired by the aviator.

The direction and velocity of the wind at various altitudes may be determined previous to a flight by means of pilot balloons. Mr. Patterson, demonstrated the method of filling the small rubber balloons with the exact amount of hydrogen necessary to give them an upward velocity of 525 feet per minute, which remains constant throughout the flight; and the way in which the altitudes and azimuths of the free balloon were determined at each minute by means of a special theodolite. A short computation gives very approximately the direction and the velocity of the upper air currents at any desired altitudes.

J. A. PEARCE, *Recorder*

NOTES FROM THE METEOROLOGICAL SERVICE

Temperature—October, 1921

The temperature in Alberta, western Saskatchewan and in Southern Manitoba was from 3 to 5 degrees above the average. Elsewhere over the Dominion it did not vary much from the average, some districts being slightly above while others were slightly below.

Precipitation

The precipitation was unusually heavy over the British Columbian Coast and in Vancouver Island and over the Lower Mainland but in parts of the Interior of the Provinces there was less than the average amount. In the Western Provinces it was quite deficient except in Southern Saskatchewan where there was a small excess. In Ontario it was below the average in the Northern portion and nearly everywhere else well above. In Quebec it was above the average and to a considerable amount in most places, whereas in the Maritime Provinces it was in all localities much below. Some of the pronounced positive departures were: Vancouver 4.50 inches; Victoria 2.40 inches; Toronto 1.80 inches; Montreal 1.60 inches; Father Point 3.40 inches. Negative departures in the Maritime Provinces varied from one and a quarter to two and three quarters inches and in the Western Provinces from a half to three quarters of an inch.

SEISMOLOGICAL NOTES FOR OCTOBER

Victoria recorded 11 disturbances during the month, and Toronto 10. Amplitudes of 2.0 mm. on the 15th, and 1.0 mm. on

the 20th, were the largest of the series. The others showed amplitudes ranging from 0.1 to 0.5 mm. The P waves on the 20th were not recorded at Toronto, but the S waves were well defined, coming in abruptly at 6h 22m 42s G.M.T., and were unusually large. The maximum phase took place 16m 30s afterwards.

J.Y.

Magnetic Disturbances, October, 1921

During the month of October the Magnetic Forces were for the most part quite normal. Only two disturbances of magnitude were recorded at Agincourt and Meanook. The first of these on the 7th and 8th began gradually during the afternoon of the 7th. Changes in Force and direction were small and very gradual up to 22 hours (75th M.T.) when the disturbance quickly changed to one of marked intensity, and continued with very rapid and large fluctuations until 8 a.m. (75th M.T.). It then returned almost as quickly to a very light disturbance with small sluggish changes which gradually died out by noon. The ranges in the different elements were at Agincourt H 452γ, Z 533γ and D 1° 55′.0 and at Meanook in D 3° 56′.0.

The second large disturbance occurred on the 11th, but was pronounced only in the Vertical Force. Beginning about midnight of the 10th, the Vertical Force at first slowly diminished to a minimum at 0h 43m (75th M.T.) of the 11th, and then slowly increased until 16h, followed by a more rapid rise to a maximum at 19h 35m and then a fairly quick return to normal. The range in Vertical Force was 245γ, whilst that in H was only 136γ, and in D 50′.0. The range at Meanook in D was 54′.5.

No sunspots were visible during the first week of October, but from the 8th to the 20th, two small groups were to be seen and during the remainder of the month two fairly large groups.

The Aurora was quite generally seen in Canada during the first two weeks and was most pronounced on the 7th. It was again visible during the last five days, but it was then of a low order.

W.E.W.J.

TEMPERATURES FOR MONTH OF OCTOBER 1921.

STATIONS	October Highest	October Lowest
Yukon		
Dawson	47	3
British Columbia		
Atlin	61	20
Agassiz	80	34
Barkerville	61	9
Kamloops	72	22
New Westminster	69	35
Prince Rupert	65	35
Vancouver	69	33
Victoria	73	39
West Provinces		
Battleford	78	23
Calgary	82	22
Edmonton	81	18
Medicine Hat	81	28
Minnedosa	73	24
Moosejaw	73	22
Oakbank	74	28
Portage la Prairie	73	29
Prince Albert	76	24
Qu'Appelle	73	20
Regina	70	19
Saskatoon	71	23
Souris	75	24
Swift Current	80	24
Winnipeg	76	26
Ontario		
Agincourt	69	32
Oak Ridges	66	30
Bancroft	60	19
Barrie	66	31
Beatrice	64	22
Bloomfield	69	28
Brantford	65	30
Chapleau	58	22
Chatham	78	29
Clinton	67	32
Collingwood	73	28
Cottam	....	....
Georgetown	67	26
Goderich	67	33
Grimsby	72	28

STATIONS	October Highest	October Lowest
Ontario—cont.		
Guelph	67	30
Haliburton	65	22
Huntsville	72	25
Kenora	64	28
Kingston	67	30
Kitchener	68	28
London	71	31
Lucknow	67	28
North Gower	80	25
Oshawa	62	30
Ottawa	73	24
Paris	85	21
Parry Sound	65	27
Peterborough	74	26
Port Arthur	66	27
Port Dover	69	34
Port Stanley	66	32
Queensborough	65	21
Ronville	63	26
Southampton	67	29
Stonecliffe	70	26
Stoney Creek	71	27
Toronto	72	33
Uxbridge	66	29
Welland	71	30
White River	64	13
Quebec		
Brome	64	16
Father Point	64	20
Montreal	64	30
Quebec	61	26
Sherbrooke	66	20
Maritime Provinces		
Charlottetown	68	28
Chatham	72	22
Fredericton	71	20
Halifax	70	22
Moncton	74	20
St. John	71	24
Sussex	71	18
Sydney	68	30
Yarmouth	68	26

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

TWO BRIGHT FIRE-BALLS

Fragments of matter must have been flying through space in our neighbourhood on the 19th and 20th of November last, as two exceptionally bright fire-balls were reported then.

Mr. Norman Mackintosh, who lives in the eastern part of Toronto, saw the first one sweep north-westerly across the sky at 8.25 p.m. on November 19. It moved very slowly and was described as follows: "A brilliant blue-white 'head,' the glare from which was as fierce as that from an electric arc; a reddish or orange-hued seeming 'chain' of fragments followed close on the 'head'; a large reddish fragment detached itself from the head, and apparently outstripped it, though really coming earthwards more slowly as the rest sped onwards; no sound was heard." Others observed the meteor, being surprised at its brilliancy.

On the next evening, November 20, at 7.05, an unusually fine fire-ball was seen at Guelph, Ont., and reported by Mr. H. Westoby. It resembled a small balloon falling in flames, directly to the south, and was followed immediately afterwards by two smaller bodies. It was of a light-green colour, and appeared to be about half the width of the sun, and moved with astonishing slowness.

To the writer it seems certain that these bodies fell to the earth and it is regrettable that they were not recovered.

APPOINTMENT OF TWO NEW DIRECTORS

The important post of director of the Harvard College Observatory, held for so many years by E. C. Pickering, has been filled by the election of Dr. Harlow Shapley to the position. Dr. Shapley is thirty-five years old and was born at Nashville, Miss. He studied at the University of Missouri, and then at Princeton, where he obtained the Ph.D. degree. From 1914 until last spring, when he went to Harvard, he was on the staff of the Mt. Wilson Observatory. At Princeton he made an extended study of the

orbits of eclipsing binaries, while at Mt. Wilson his studies of the star clusters, especially Messier 13, have led to profound speculations regarding the size of the sidereal universe. According to Dr. Shapley the sun is not at the centre of the galaxy but very far indeed from it; also, the great star-clusters are at immense distances from the plane of the galaxy and appear to be falling into it.

Dr. Joel Stebbins, the genial secretary of the American Astronomical Society, has been appointed director of the Washburn Observatory and professor of astronomy in the University of Wisconsin, succeeding Prof. G. C. Comstock, who retires on July 1, 1922. Dr. Stebbins has been a member of the department of astronomy of the University of Illinois since 1903 and director of the observatory since 1913. Professor Comstock has been director of the Washburn Observatory for 32 years and dean of the Graduate School from 1906 to 1920.

The death of Miss Henrietta S. Leavitt, of the Harvard College Observatory, occurred on December 19. For nearly twenty years she was one of the most capable assistants and the results of her work are to be found in important contributions to the Harvard *Annals*. The present writer can testify to her ability in her special department and also to her willingness to give advice and assistance to others.

C. A. C.

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